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UBER TECHNOLOGIES, INC.
and OTTOMOTTO LLC

UNITED STATES DISTRICT COURT

NORTHERN DISTRICT OF CALIFORNIA

SAN FRANCISCO DIVISION

WAYMO LLC,

Plaintiff,

v.

UBER TECHNOLOGIES, INC., OTTOMOTTO LLC; OTTO TRUCKING LLC,

Defendants.

Case No. 3:17-cv-00939-WHA

SUPPLEMENTAL DECLARATION OF SCOTT BOEHMKE IN SUPPORT OF DEFENDANTS' SUR-REPLY TO PLAINTIFF WAYMO LLC'S MOTION FOR PRELIMINARY INJUNCTION

Date: May 3, 2017
Time: 7:30 a.m.
Ctrm: 8, 19th Floor
Judge: The Honorable William Alsup

Trial Date: October 2, 2017

REDACTED VERSION OF DOCUMENT SUBMITTED UNDER SEAL

I, Scott Boehmke, declare as follows:

1. I am an engineering manager within the Advanced Technologies Group at Uber Technologies, Inc. ("Uber"), where I am responsible for hardware development and application in Uber's self-driving vehicle project. I understand that Waymo has filed a lawsuit against Uber, Ottomotto LLC ("Otto") and Otto Trucking LLC in the U.S. District Court for the Northern District of California. I submit this supplemental declaration in support of Defendants' Sur-Reply to Waymo LLC's ("Waymo") Motion for Preliminary Injunction. I have personal knowledge of the facts set forth in this declaration and, if called to testify as a witness, could and would do so competently.

Prior Work Reflecting Non-Uniform Beam Spacing

2. I understand that Waymo's expert argued in his reply declaration that my work relating to beam spacing prior to my first meeting with Otto, which I had included as exhibits to my earlier declaration, only shows (1) distinct "zones" in which groups of lasers are equally distributed, and (2) distributions of lasers where the differences between zones are "symmetrical." To the contrary, I have been working on developing non-uniform beam spacing for LiDAR sensors since 2015, including beam patterns for which the spacing between adjacent laser diodes varies continuously and non-symmetrically. Paragraphs 3 to 5 below address the work I performed prior to my first meeting with anyone from Otto in late April 2016, which I also described in my prior declaration.

3. Figure 1 is a true and accurate annotated excerpt from my October 2015 "LADAR Design Notebook"[1] showing schematic and spacing parameters of a variably-spaced diode design for Velodyne's VLP-32, which has 32 diodes. I included an unannotated copy of this excerpt in paragraph 8 of my earlier declaration. The blue dots on the right hand side of the excerpt represent the vertical positions of each of the 32 diodes, with the diodes at the top and bottom [redacted]. The chart to the right of the schematic provides the precise angles of each diode, as well as the change in angular orientation or elevation

[1] A true and correct copy of this document was previously attached as Exhibit B to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

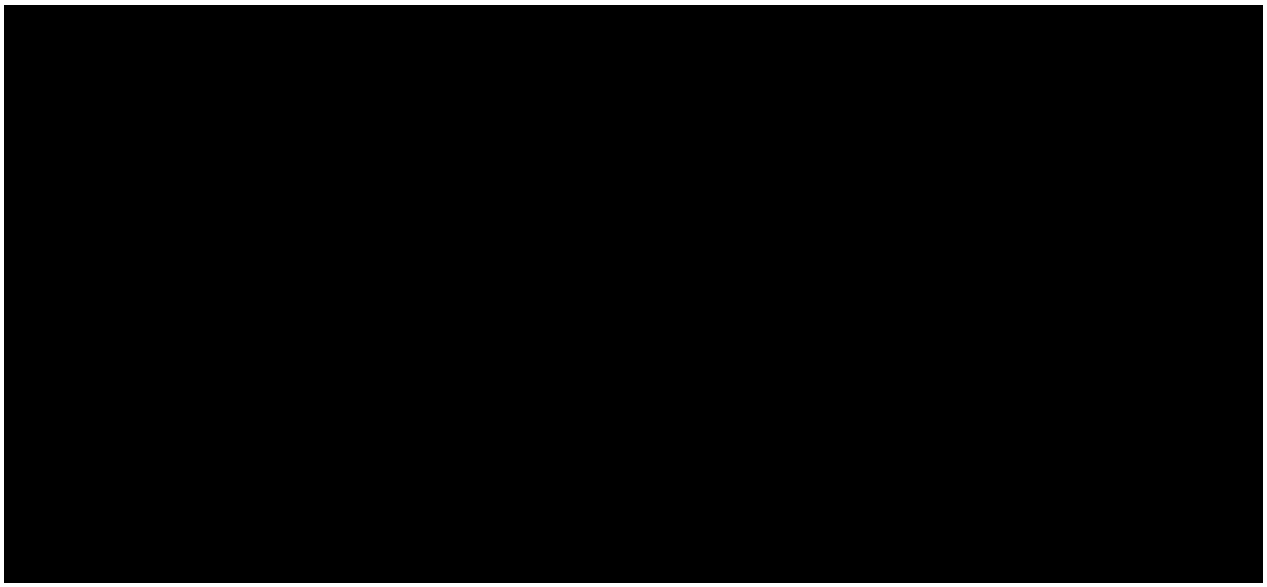
(or "deltas") between the angles. As is evident both visually in the schematic and numerically in the corresponding chart, the "angular elevation" of the 32 laser diodes is [redacted].

4. As I mentioned in my earlier declaration, [redacted] was one of the potential suppliers I was evaluating in 2015 to provide LiDAR sensors customized to Uber's beam spacing and field of view requirements. From November 2015 through March 2016, I worked on developing the custom beam patterns and parameters necessary for Uber's automotive use, taking into account the technical constraints of [redacted] LiDAR sensors. Figure 2.A is a true and accurate annotated excerpt of a request for quotation[2] (RFQ) that Uber provided to [redacted] on December 7, 2015 for a LiDAR sensor capable of providing Uber's requested parameters and

[2] A true and correct copy of this document was previously attached as Exhibit D to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

field of view requirements (i.e., a total vertical field of view of 45 degrees, 102 lines or channels, "non-uniform spacing," and 0.16 degrees minimum gap). Figure 2.B is a true and accurate annotated excerpt of the preliminary specifications[3] for a 64-channel LiDAR sensor customized to Uber's parameters and field of view requirements that Uber provided to [redacted] on December 15, 2015. Similar to the RFQ, the preliminary specifications envisioned a total vertical field of view of 45 degrees and [redacted], providing precise vertical positions of the 64 laser channels and the beam separation (i.e., the change in angular orientation) between each laser channel. The pattern clearly indicates a distribution of laser channels that was under consideration in 2015, where the adjacent pairs of laser diodes had different beam separations. For example, the beam separation from [redacted], where each pair of adjacent laser diodes had different beam separation. Laser channels 3-9 are not grouped into "zones" where multiple lasers within each zone are equally distributed. Moreover, the differences between the beam separations are not "symmetric." As shown in the chart, the beam separation between laser channels 5 and 6 is [redacted], the beam separation between laser channels 6 and 7 is [redacted], and the beam separation between the laser channels 7 and 8 is [redacted]. Here, the difference between the beam separation in laser channels 5 and 6 and laser channels 6 and 7 [redacted] is different from the difference between beam separation in laser channels 6 and 7 and laser channels 7 and 8 [redacted]

[3] A true and correct copy of this document was previously attached as Exhibit E to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.



5. As I mentioned in my earlier declaration, Uber entered into a contract with [redacted] in March 2016 under which [redacted] agreed to develop for Uber [redacted] based on Uber's custom beam patterns and parameters. Figure 3.A is a true and correct CAD rendering of the [redacted] dual-stack, excerpted from my May 2016 "LIDAR Thoughts."[4] Figure 3.B is a true and correct annotated excerpt of the final specifications[5] Uber provided to [redacted] to build a pair of [redacted] according to Uber's custom beam pattern and parameters. The annotated chart in Figure 3.A clearly shows a distribution of laser channels in the [redacted] dual-stack, from [redacted], where each pair of adjacent laser diodes had different beam separations. Here, the differences between the beam separations are also not symmetric. For example, as annotated below in Figure 3.B, the beam separation between laser channels 18 and 19 is [redacted], the beam separation between laser channels 19 and 20 is [redacted], and the beam separation between the laser channels 20 and 21 is [redacted]. Here, the difference between the beam separation in laser channels 18 and 19 and laser channels 19 and 20 [redacted]

[4] A true and correct copy of this document was previously attached as Exhibit H to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

[5] A true and correct copy of this document was previously attached as Exhibit F to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

[redacted]) is different from the difference between beam separation in laser channels 19 and 20 and laser channels 20 and 21 [redacted]

[redacted]

Figure 3.A	Figure 3.B

Multiple Laser Diodes on a Single Curved Printed Circuit Board (PCB)

6. I understand that Waymo's expert argued in his reply declaration that the first document showing placement of multiple laser diodes on a single PCB was in my May 2016 LiDAR Thoughts document, included as Exhibit H of my earlier declaration. To the contrary, I have been considering positioning multiple laser diodes on a curved edge of a printed circuit board since December 2015. Paragraphs 7 to 10 address my work in this area.

7. Figure 4 is a true and accurate excerpt from my December 2015 LADAR Design Notebook[6] showing a LiDAR concept having separate transmit and receive lenses and arranging three laser channels (represented in blue, green, and red) along a curved transmit board labeled "Lasers" behind a simple transmit ("Tx") lens. I included this excerpt in my earlier declaration. The laser diodes are arranged in a curve because the geometry of a simple lens, such as a single

[6] A true and correct copy of this document was previously attached as Exhibit C to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

transmit lens, would create a curved focal plane instead of a flat focal plane. The geometry of this curve is defined by the focal length of the lens.

Figure 4

8. Figures 5.A and 5.B show true and accurate annotated excerpts of a printed circuit board layout with three laser diodes die attached and wire bonded to bond pads that Uber had created on March 29, 2016 to illustrate how tightly we could pack the laser diodes and drivers on a single printed circuit board (PCB). I understand that the layout in Figure 5.A was previously produced to Waymo as UBER00008423, and I informed Waymo's attorney to the existence of this document during my deposition in this case.[7] Figure 5.B is an enlarged and excerpted view of the same layout that more clearly illustrates the placement of the laser diodes and the bond pads along the edge of the PCB. As this alternative view shows, we were able to reduce the spacing between the laser diodes down to 2.3 millimeters.

[7] *See* Boehmke Dep. 63:17-25, April 17, 2017. A true and correct excerpt of this section of my deposition is attached as Exhibit E to this declaration.

Figure 5.A	Figure 5.B

9. Further, as I explained in my earlier declaration, Uber was considering multiple options for LiDAR sensors as of May 18, 2016, three of which were laid out in my May 2016 "LIDAR Thoughts."[8] Plan A was the [redacted] "dual-stack," which contrary to Waymo's expert's assumption, Uber is still pursuing. I understand that there was a PanDAR sensor that stacked two commercially available Velodyne HDL-32 sensors to illustrate the concept of foveated vision sensing in the LiDAR context.[9] The [redacted] dual-stack that Uber was considering was designed for automotive use with a foveated beam pattern different from the interleaved design in the PanDAR sensor, and was intended to overcome the technical constraints of commercially available LiDAR sensors, such as the Velodyne HDL-32. Plan B was to build an in-house diode-based LiDAR sensor that would be simpler to fabricate and would have improved specifications over [redacted] then-existing LiDAR sensors. Figure 6 is a true and correct excerpt from my May 2016 "LIDAR Thoughts" listing some potential improvements on Velodyne's designs, such as having [redacted] and as few boards

[8] A true and correct copy of this document was previously attached as Exhibit H to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

[9] A true and correct copy of this document was previously attached as Exhibit 4 to Dr. Paul McManamon's declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

as possible to simplify alignment (e.g., [redacted]). This LiDAR concept described in Plan B later became known as "Fuji."

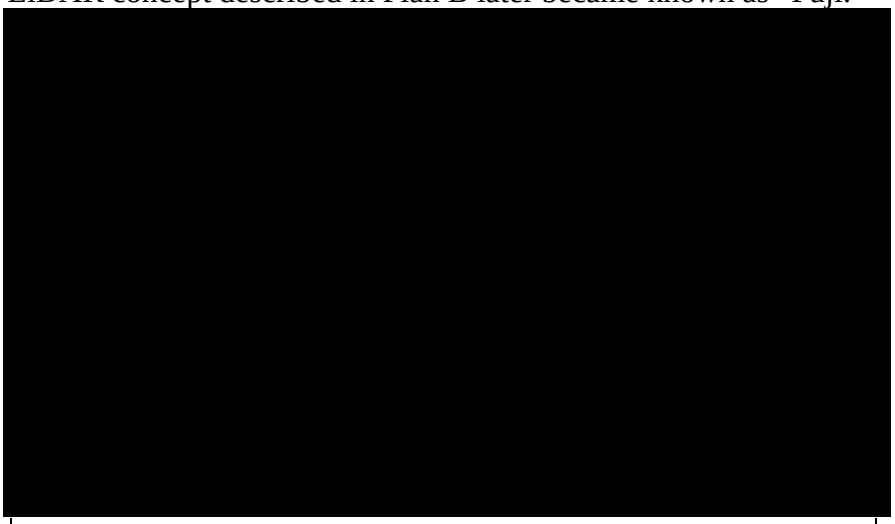


Figure 6

Plan C was to use a fiber laser design based on Uber's discussions with Otto in late April and May 2016, which included discussions about the possibility of using eight fiber lasers that were potentially split in four, six, or eight, to allow for 32, 48, and 64 beams respectively. This LiDAR concept described in Plan C later became known as Spider, a design that Uber has since abandoned.

10. I was considering placing multiple laser diodes on a curved PCB to reduce the number of transmit boards, which would simplify alignment between the laser diodes and the detectors. As shown in Figure 6 above, which describes what later became known as Fuji, I was considering a design having all laser diodes on one board (e.g., [redacted]). However, we realized that having two cavities and mounting 32 laser diodes on a single PCB per cavity did not provide enough spacing to accommodate the laser diodes' circuits and associated components. This conclusion was informed in part by my prior determination, shown in Figure 5B, that a minimum spacing of at least 2.3mm was required between laser diodes. James then suggested in an email to me, dated October 28, 2016, that we should [redacted] for each of the two cavities between the laser diodes' circuits

and associated components.[10] After further discussions with the LiDAR team, including James Haslim, it became evident that within each cavity, the 32 laser diodes would need to be distributed across [redacted] to provide sufficient spacing. Based on these discussions, I created beam spacing and angles for what became the Fuji design, which has two cavities and [redacted] per cavity. Figure 7 is a true and correct excerpt from my November 2016 beam spacing and angles summary[11] showing the assumptions used in the calculations of beam spacing for the Fuji device. This document shows that we independently came up with the design of a [redacted] (i.e., 2 separate optical cavities).

[redacted]

Figure 7

Anthony's Involvement in the Fuji Device

11. I understand that Waymo cites two email exchanges in June 2016 as evidence that Anthony Levandowksi "provided direction" to me, and contends that my development of Fuji's beam spacing was not "independent." I disagree with Waymo's contentions. As explained

[10] A true and correct copy of this document was previously attached as Exhibit A to James Haslim's April 7, 2017 declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction. This document was also introduced and designated as Exhibit 56 during my deposition.

[11] A true and correct copy of this document was previously attached as Exhibit I to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

previously, including in my deposition in this case, I had independently come up with [redacted] patterns before these June 2016 emails (the emails related to Plan C and not Fuji.)[12]

12. As I explained in my prior declaration, I independently created the beam spacing and angles captured in my November 2016 summary,[13] which was based on beam spacing work that I had started as early as October 2015, and I understand that James and his team used the data in this summary to generate the initial optical cavity and transmit PCB designs for Fuji.

13. At the time that we were considering a pivot from Spider to Fuji in late October 2016, Anthony Levandowski was not involved in the day-to-day operations of the LiDAR team, and to my knowledge did not provide input on the technical details of the Fuji design. As I explained in my deposition, Anthony Levandowski did not direct the LiDAR team to pivot from Spider to Fuji, but instead deferred to the engineers on the LiDAR team and on their judgment that Spider was not a technically viable design and their recommendation to pursue a bistatic, diode-based LiDAR design.[14] Exhibit A, attached hereto, is an email exchange between Eric Meyhofer, James Haslim, Dan Gruver, and me regarding the feasibility of pivoting from V1 (i.e., Spider) to V2 (i.e., a new diode-based design, which became Fuji).[15] In this email, Eric Meyhofer stated that he had spoken with Anthony and had promised Anthony that [redacted] Exhibit B, attached hereto, is a true and correct copy of the email from James Haslim inviting Eric Meyhofer, Daniel Gruver, and me to edit a spreadsheet comparing design considerations in Spider (i.e., "1550") and a new diode-based design that later became Fuji (i.e., "905").[16] Notably, Anthony Levandowski was not

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[12] *See* Boehmke Dep. 38:12-14. A true and correct excerpt of this section of my deposition is attached as Exhibit E to this declaration.

[13] A true and correct copy of this document was previously attached as Exhibit I to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.

[14] *See* Boehmke Dep. 42:4-19, 48:7-48:9. A true and correct excerpt of this section of my deposition is attached as Exhibit E to this declaration.

[15] A true and correct copy of this document was provided to Waymo as UBER00008592 and was introduced and designated by Waymo as Exhibit 55 in my deposition.

[16] A true and correct copy of this document was provided to Waymo as UBER00008589.

included in this invitation. Exhibit C, attached hereto, is a true and correct copy of the spreadsheet referred to in Exhibit B.[17]

Comparison between [redacted] Dual-Stack and Fuji

14. I understand that Waymo's expert argued in his reply declaration that my work relating to beam spacing prior to my first meeting with Otto was very different from my work on Fuji. To the contrary, I applied similar approaches to determine the desired beam angles for both the [redacted] dual-stack that Uber was considering as early as November 2015, and the Fuji design. In calculating the distribution and quantity of light beams in both the [redacted] dual-stack and Fuji, I took into account various parameters, including vehicle speed, permissible deceleration rate, reaction time, mounting geometry of the sensor, anticipated road geometry, minimum detectable obstacle, and manufacturing tolerances.

15. When I documented my thoughts for the [redacted] dual-stack ("Plan A") and the Fuji device ("Plan B") in the May 2016 "LIDAR Thoughts," I used the same base assumptions. Figure 7 is a true and correct excerpt from my May 2016 "LIDAR Thoughts" that explains the same base assumptions are used in the subsequent slides discussing Plan A and Plan B.

[17] I understand that a true and correct copy of this document was provided to Waymo as UBER00008487.

Figure 8

16. When I finalized the beam spacing for the [redacted] dual-stack in March 2016, I designed it to have no larger than a [redacted] When I designed the beam spacing for the Fuji device in November 2016, I designed it to have no larger than a [redacted] because I was no longer constrained by the limitations and poor manufacturing tolerances of [redacted]. I was able to design Fuji to have tighter beam spacing, allowing Uber's vehicle to see smaller targets at the same distances than the [redacted] dual-stack. Further, when I designed the [redacted] dual-stack, I had envisioned applying a less aggressive deceleration [redacted] and constant speed regardless of road slope, whereas for Fuji, I allowed for more aggressive deceleration [redacted] and to reduce the vehicle speed when crossing steep slopes.

17. Exhibit D is a true and correct copy of my calculations underlying the final specifications for the [redacted] dual-stack.[18] Figure 9.A is a true and correct excerpt of the assumptions for the beam spacing calculations for the [redacted] dual-stack in Exhibit D, and

[18] The final specifications for the [redacted] dual-stack were provided as Exhibit F to my earlier declaration.

Figure 9.B is a true and correct excerpt of the assumptions for the beam spacing calculations for Fuji, which I previously included with my earlier declaration.[19] A comparison of the calculations for the [redacted] dual-stack and the calculations for Fuji show that I used substantially the same parameters to calculate the beam spacing for the [redacted] dual-stack and Fuji. These parameters include the rate of deceleration, sensor and pipeline delays, sensor height, reaction time and distance, vehicle speed, and max slope at various speeds.

[redacted]

Figure 9.A	Figure 9.B

I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct. Executed this 28th day of April, 2017, in Pittsburgh, Pennsylvania.

Scott Boehmke

[19] A true and correct copy of my beam spacing calculations for Fuji was previously attached as Exhibit I to my earlier declaration in support of defendants' opposition to plaintiff's motion for preliminary injunction.